Factors Influencing Occurrence, Scale, Mobility, Runout, and Morphology of Mass Movements on the Continental Slope

Jacques Locat
Department of Geology and Geological Engineering, Laval University
Sainte-Foy, Québec, CANADA G1K 7P4
phone: (418) 656-2179, fax: (418) 656-7339, email: locat@ggl.ulaval.ca

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LONG-TERM GOALS

The goal of this proposal is an improved understanding of relationships between sedimentation, environment, and the morphology of continental slopes. Reaching the goal requires an understanding of how geotechnical and physical properties develop in marine sedimentary deposits on the continental terrace and how these properties influence sediment transport processes and the development of geomorphology. This goal will be accomplished through investigations within the northern California and New Jersey study areas and in the Adriatic and Gulf of Lion regions in collaboration with European scientists partners through the EuroSTRATAFORM Project. The various components of this project are part of a concerted effort between the geotechnical groups at the USGS and Laval University. Their activities are very much interwoven but, for administrative reasons, annual reports are provided separately.

OBJECTIVES

Identify factors that can be mapped regionally and that determine where and how slope failures occur; derive a basis for producing regional maps that indicate relative landslide susceptibility. Model shear strength development with depth and incorporate this model into continental slope stability, post-failure behavior, and bedform processes. Observe and model pore pressure development in continental slopes. Analyze the relationship between seismic intensity, sediment instability and slope processes. Integrate these elements into geo-hazards assessment.

APPROACH

Our research focuses on the factors that lead to variations in the sedimentological and environmental conditions determining slope failure. We develop improved correlation between engineering classifications and strength factors. We relate compressibility, physico-chemical properties and strength to sediment microstructure, observed using SEM techniques. We simulate sediment accumulation in specially designed large cells. We measure sediment rheological properties in a viscometer. Geotechnical properties are related to sediment density state, obtained from detailed logs of downcore variability of sediment density and sound velocity. Basic strength parameters are obtained using triaxial drained and undrained tests and undrained cyclic tests. Using available bathymetry, and seismic profiles, we develop models tested for stability and mobility. Seismic shaking variations are evaluated probabilistically by seismologists. Pore pressures are either determined in situ by means of the Excalibur probe (AGC-Atlantic) or estimated using sedimented rates and consolidation theory. If

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14. ABSTRACT

The goal of this proposal is an improved understanding of relationships between sedimentation, environment, and the morphology of continental slopes. Reaching the goal requires an understanding of how geotechnical and physical properties develop in marine sedimentary deposits on the continental terrace and how these properties influence sediment transport processes and the development of geomorphology. This goal will be accomplished through investigations within the northern California and New Jersey study areas and in the Adriatic and Gulf of Lion regions in collaboration with European scientists partners through the EuroSTRATAFORM Project. The various components of this project are part of a concerted effort between the geotechnical groups at the USGS and Laval University. Their activities are very much interwoven but, for administrative reasons, annual reports are provided separately

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there is charging by bubble-phase gas, or if earthquake shaking disrupts the sediment fabric and causes it to collapse with a resulting increase in the pressure of interstitial fluids. Driving stresses are balanced against strength variations in a geographic Information System (GIS) to obtain a regional estimate of relative slope stability.

Key individuals, at Laval: Jacques Locat, Jean-Marie Konrad, Serge Leroueil, Priscilla Desgagnés, and Marie-Claude Lévesque: strength and compressibility measurements, SEM studies, rheology measurements, and simulation of sediment accumulation.; at the USGS: Homa Lee, Kevin Orzech, Dianne Minasian, and Pete Dartnell: physical property logs of sediment cores and relations between geotechnical and classification properties, algorithms relating sediment properties, environmental factors, and slope stability within the framework of a GIS.

WORK COMPLETED

During FY 02, a large proportion of our research efforts were directed towards completing the STRATAFORM objectives on the New Jersey Margin by completing the slope stability analysis of the Hudson Apron by various analyses using SLOPEW package to investigate the potential role of gaz hydrates and groundwater pore pressure on the stability of the Hudson Apron. This involved more advance (triaxial tests, and SEM analyses) test on various cores form the area. The testing has been done mostly on the 1999 Marion Dufresne cores. The analysis of the Hudson Apron rheological properties has been investigated and will be used as part of BING to simulate various conditions for debris flows along the slope of the Hudson. We also carried out, at the USGS during the summer of 2002, a series of cyclic simple shear tests in order to test our hypotheses on the process of seismic strengthening on Francisco Bay muds. This has been done in preparation for further tests on the Adriatic sediments to be obtained in FY03. These results were also share with COSTA partners at various conferences in North America and Europe, which already include some EU-STRATAFORM partners.

RESULTS

The completed (Desgagnés 2002) detailed slope stability analysis of the Hudson Apron sediments, mostly lying on a slope of 4° (se Figure 1 for the cross section analyzed), indicates that very high pore pressures are required to generate instability. The excess pore pressure required would be equivalent to a r_u (pore pressure ratio) value between 0.8 an d0.9, which at a depth of about 200m, would correspond to a pore pressure of about 150-1500 kPa. Causes which were investigated include: (1) under-consolidation, (2) groundwater seepage from a nearby coastal aquifer, (3) gaz hydrates decomposition, and (4) earthquake triggering. At this time, we believe that more than one cause needed to be activated for the slide to take place. Advanced geotechnical testing of the Hudson Apron sediments indicates that they are normally consolidated, at least in the section investigated (*i.e*. to a depth of 38m). The rheological properties of the Hudson Apron sediments are quite similar to those of other sediments and follow the general relationship proposed by Locat (1997) for the liquidity index range tested between 1.3 to 3.5. As this STRATAFORM project is approaching to an end, we also put significant efforts in completing major papers which were published, accepted in 2002 or are being completed. These are a review on submarine mass movements (Locat and Lee 2002), a paper on sediment waves (in press at Marine Geology). Our work on bioturbation and seismic strengthening has been published in 2002 (Locat et al. 2002). Our overall finding were compiled and presented at the first EuroSTRATAFORM workshop in Winchester (UK), early in September 2002. We are also currently preparing for an upcoming cruise on the New Jersey margin (starting on September 26th) were cores should be collected using the GLAD800.

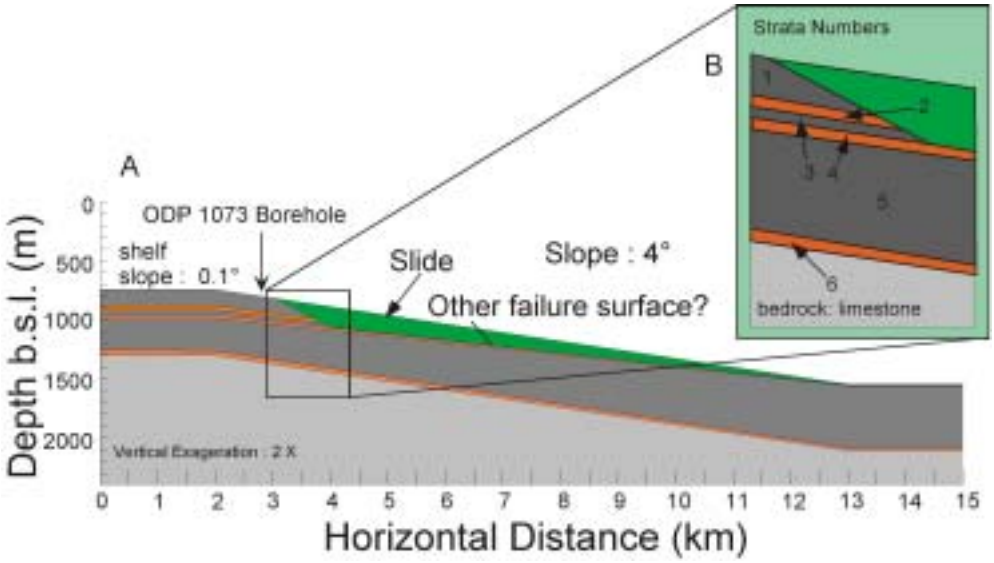

Figure 1. Hudson Apron cross section analyzed for slope stability (Desgagnés 2002, Locat et al. 2003, in prep.).

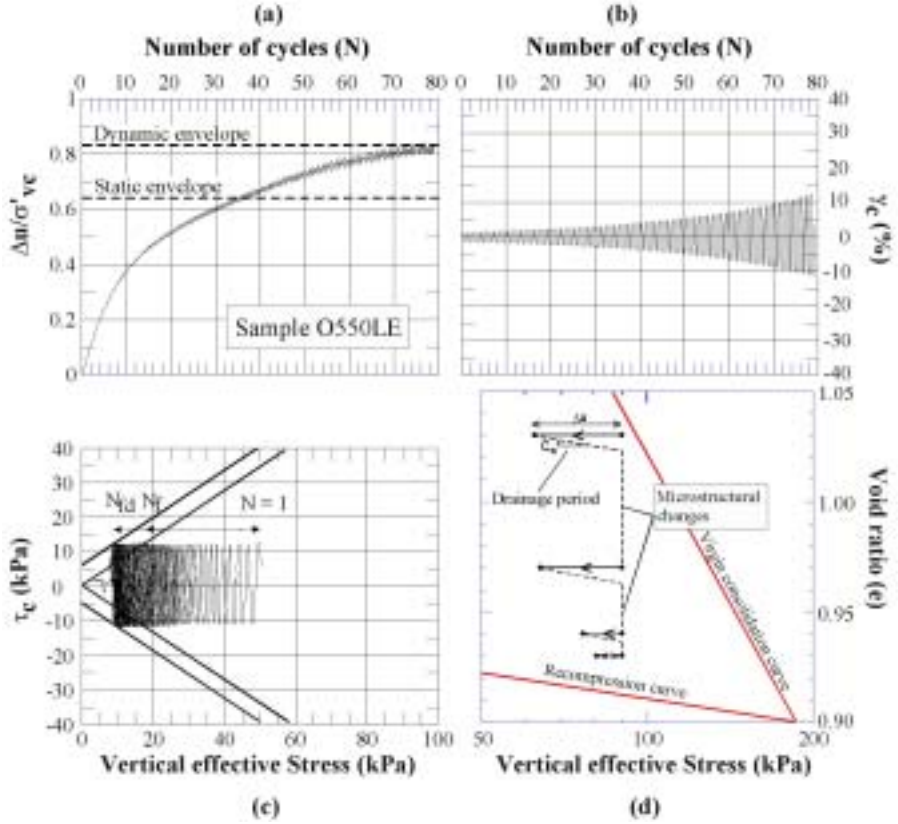

Figure 2. Seismic activity as a way of strengthening soils (Locat and Lee 2002).

IMPACT/APPLICATION

Relationships developed in this project show the importance of sediment liquidity index and seabed density profiles in representing the behavior of marine sediment. These values can be used to predict regional slope stability and the rheological behavior of debris flows. General strength-density relationships can be used for modeling sediment accumulation and stability.

TRANSITIONS

Geoacoustic properties are being used by mappers and acousticians to identify lithologies acoustically (Locat and Sanfacon, 2002). Rheological properties are being used by modelers to represent debris flows (Imran et al. 2001). Landslide generation models are being used by landscape evolution modelers. Offshore research groups interested in margin (January 1999 Paris Workshop, see Locat 2001) and in oil and energy development were used as a platform to present our knowledge on submarine slope stability and hazard acquired as part of STRATAFORM . a major opportunity was also provided in June 2000 when we were invited to give a keynote lecture on submarine mass movements at the 8th International Symposium on Landslides in Cardiff (Locat and Lee 2002). Our knowledge on submarine mass movement, developed as part of STRATAFORM, has been put to use in the analysis of tsunami generation. There appears to be more and more cases of tsunamis which are believed to result from submarine mass movements. This is particularly important for coastal communities like in the Los Angeles area (Locat *et al*. 2001)

RELATED PROJECTS

Lee has developed a USGS project to investigate sediment and pollutant transport on the Los Angeles margin that uses techniques produced by STRATAFORM. Locat is investigating the behavior of a newly formed sediment layer acting as a natural cap over contaminated sediment in Canada. The development of this project benefited from approaches developed within STRATAFORM. Recently, a group of Canadians led by J. Locat, and H. Lee developed a new project with project COSTA (COntinental Slope STAbility) in Europe that will last until 2004.

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